

**(12) UK Patent Application (19) GB (11) 2 294 129 (13) A**

**(43) Date of A Publication 17.04.1996**

(21) Application No 9420797.4

**(22) Date of Filing 14.10.1994**

(71) Applicant(s)  
George Hans Lowe  
32 Homestead Road, Rivonia, Sandton, South Africa

(72) Inventor(s)  
**George Hans Lowe**

(74) Agent and/or Address for Service  
Gill Jennings & Every  
Broadgate House, 7 Eldon Street, LONDON,  
EC2M 7LH, United Kingdom

(51) INT CL<sup>6</sup>  
G21C 17/00, G05B 23/02, G21D 3/02 3/04

(52) UK CL (Edition O)  
G3N NGK2 NG1A5 N262 N287 N381 N387 N402X N404  
G6C CDF C63X C63Y  
U1S S1905 S1907

(56) Documents Cited  
EP 0411869 A2      EP 0099681 A1      US 4853175 A

(58) Field of Search  
UK CL (Edition N ) G3N NGK2 NGK2A NGK2B NG1A1  
NG1A3 NG1A5 NG1A9 , G8C CDF  
INT CL<sup>6</sup> G05B 9/02 23/02 , G21C 17/00 , G21D 3/02  
3/04 3/06  
ONLINE:- WPI

**(54) Fault monitoring system**

(57) An indicating system 10 for use in a plant where predetermined action is required upon the occurrence of a fault condition includes a data processing facility 12 and a data inputting facility 16 for inputting data into the data processing facility 12. A graphic display device (Figure 2) is connected to the data processing facility for displaying, in graphic form, action to be taken by an operator upon the occurrence of a particular fault condition. A time indicating unit 20 is connected to the data processing facility for indicating the time available to the operator to take the appropriate action to bring the plant to a required state.

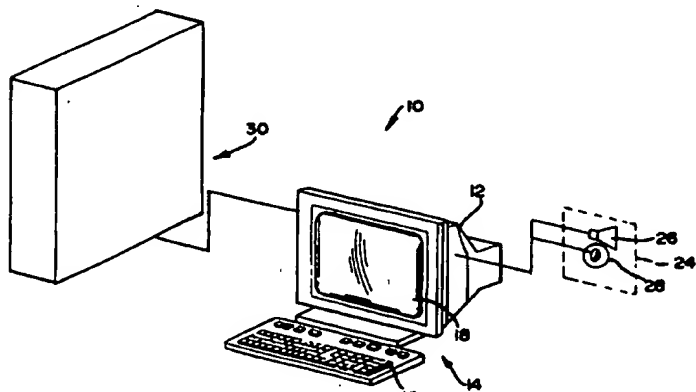


FIG 1

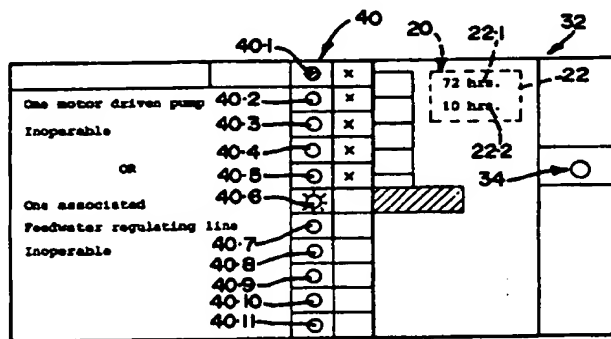


FIG 2

GB 2294 129 A

1/2

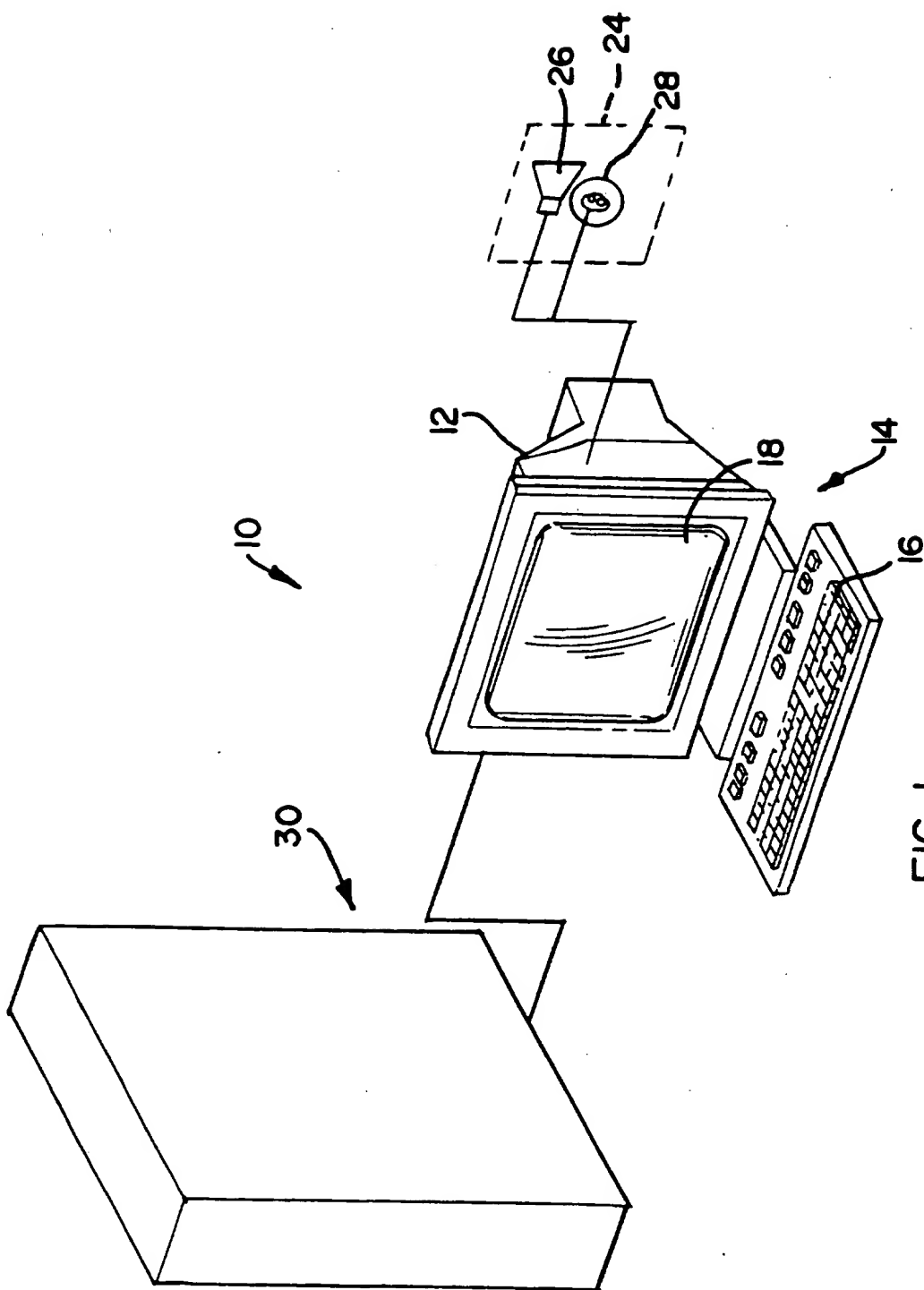


FIG 1

2/2

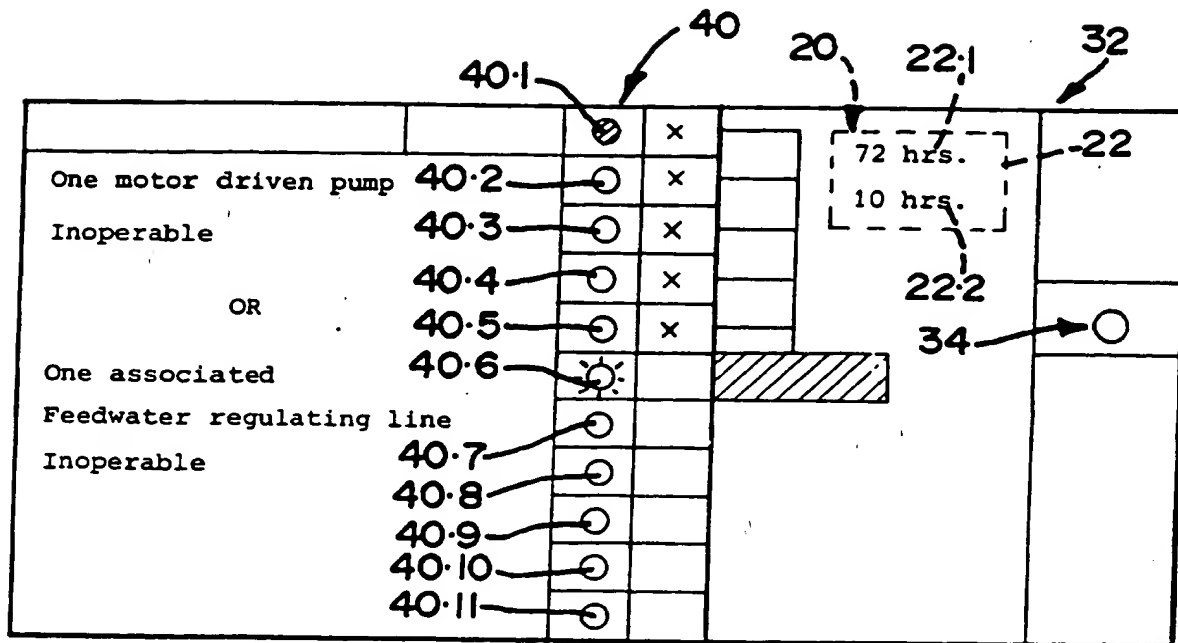


FIG 2

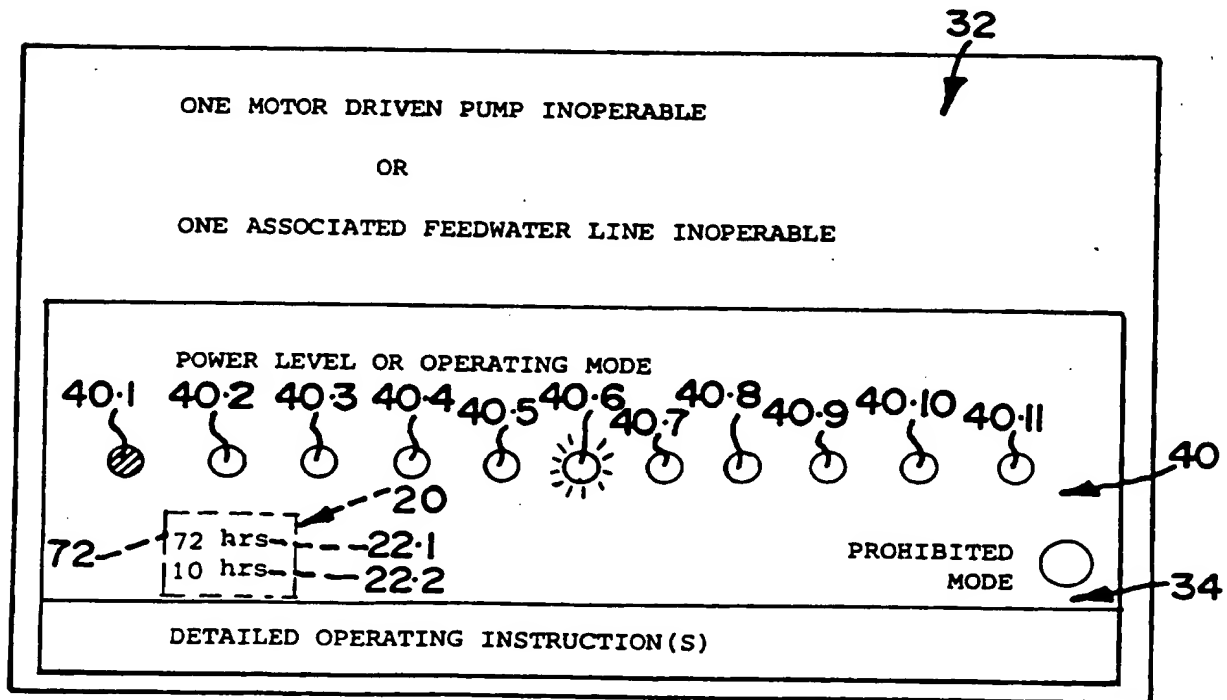


FIG 3

AN INDICATING SYSTEM

THIS INVENTION relates to an indicating system. The invention relates particularly to an indicating system for use in a plant where predetermined action is required upon the occurrence of a fault condition. While the invention has particular application in nuclear power stations and will, for ease of explanation, be described with reference to that application hereinafter, it will readily be appreciated that the system could be used in other process plant applications.

According to the invention, there is provided an indicating system for use in a plant where predetermined action is required upon the occurrence of a fault condition, the indicating system including

- a data processing means;

- a data inputting means for inputting data into the data processing means;

- a graphic display means connected to the data processing means for displaying, in graphic form, action to be taken by an operator upon the occurrence of a particular fault condition; and

a time indicating means connected to the data processing means for indicating the time available to the operator to take the appropriate action to bring the plant to a required state.

Conveniently, the graphic display means may, additionally, display action to be taken in a narrative form.

The graphic display means may be controlled by the processing means and is operable to display, in a graphic form, the action to be taken upon the occurrence of the particular fault condition. Thus, in the case of a nuclear power station, when a fault condition occurs, the display means may display the operating, failsafe or fallback state to which a reactor of the nuclear power station must be taken. Hence, for example, in the case of an auxiliary feedwater regulating line being inoperable, the lower state to which the reactor must be taken may be the normal intermediate shutdown state with residual heat removal system valved in. This must be effected within a specified time period.

In this specification, the term "operator" is to be understood in a broad sense as referring to any personnel of the plant who would operate the plant and/or need to respond to a fault condition.

The data processing means may comprise a computer.

Then, the data inputting means could be in any one of a variety of formats. Thus, for example, the data inputting means may include a manual inputting means, conveniently, a keyboard of the computer, by means of which the operator enters data into the data processing means. In addition, or instead, the data inputting means may include an automatic inputting means whereby, upon the occurrence of the fault condition, a signal is input into the data processing means. Further, if appropriate, the data inputting means could be an emergency response facility of the plant.

The time indicating means may comprise a clock and a time display means, the time display means being driven by the clock to be decremented as time passes so that the operator has an indication of the reducing time available in which to carry out the necessary remedial action.

The time display means may be in the form of a counter. The counter may be operable, under the action of the data processing means, to change format depending on the urgency of the situation. Hence, for example, upon the occurrence of a fault condition, the counter may flash in a particular colour, for example, white.

Thereafter, depending on the urgency of the situation, the displayed time may change colour, for example, to amber and then to red.

The system may include a discernible alarm means connected to the data processing means to be activated upon the occurrence of a particular incident, for example, when the counter changes colour. The discernible alarm means may comprise an audible alarm means and/or a visual alarm means.

The alarm means may be of a continuous or "nagging" type which requires a positive response by the operator. Further, the alarm means may comprise an annunciator to alert a supervisor in a remote location.

The system may include a data storage means which contains information relating to graphics of the graphic display means, the time indicating means as well as action taken by the operator upon the occurrence of the fault condition and how long the condition was allowed to continue before the required operating state of the plant was attained.

The data storage means may, additionally, contain information relating to detailed procedures to be followed by the operator in carrying out the appropriate action.

The invention extends also to a method of operating a plant where predetermined action is required upon the occurrence of a fault condition, the method including

graphically displaying a sequence of actions to be taken by an operator on the occurrence of a fault condition in the plant; and

indicating permissible time limits in which the action must be taken.

The method may include making available predetermined data to enable the sequence of actions to be displayed graphically. The data may be made available automatically or manually.

The method may include displaying the time in a predetermined format and causing the displayed time to be decremented.

The method may include displaying cascading or additive fault conditions or a decision tree to aid the operator in deciding upon appropriate remedial action or to prepare for possible future actions.

Further, the method may include, as critical time periods are approached, causing the displayed time to change format, for example, causing the displayed time to change colour.



Also, the method may include, upon the occurrence of a fault condition, activating an alarm means.

The invention is now described by way of example with reference to the accompanying diagrammatic drawings.

In the drawings,

Figure 1 shows a schematic diagram of an indicating system, in accordance with the invention;

Figure 2 shows a first example of a display of the system; and

Figure 3 shows a second example of a display of the system.

Referring to Figure 1 of the drawings, an indicating system, in accordance with the invention, is illustrated and is designated generally by the reference numeral 10. As indicated above, the system 10 is intended particularly for use in a nuclear power station environment and shall be described with reference to that application hereinafter.

The system 10 comprises a data processing means in the form of a computing device 12. Conveniently, the computing device 12 is a personal computer (PC). A data inputting means 14 is connected

to the computer 12. The data inputting means 14 can be in any one of a variety of formats. Thus, the data inputting means could be a manual inputting means such as a keyboard 16 of the computer. Access may be granted only after the insertion of a predetermined access code, to improve the security of the system 10.

Instead, or in addition, the data inputting means could be an automatic inputting means such as a surveillance input via a push-button panel, or a "permit-to-work" (PTW) input, both of which are input via remote terminals using a predetermined access code at all times. Still further the computer 12 could be connected to an emergency response facility of the nuclear power station. This latter input may be effected from a process computer of the nuclear power station only.

The system 10 includes a display means which, conveniently, is a screen display device 18 of the computer 12. The display device 18 displays thereon, in graphic form, action to be taken by an operator of the system 10 upon the occurrence of a particular fault condition, as will be described in greater detail below.

The system 10 also includes a time indicating means, illustrated schematically at 20 in Figures 2 and 3 of the drawings. The time indicating means 20

indicates the time available to the operator of the system 10 to take the necessary or relevant action.

The time indicating means 20 comprises a clock (not shown) controlled by the computer 12 and a time display means or counter 22 which is driven by the clock to be decremented as time passes so that the operator has a ready indication of the reducing time available in which to carry out the necessary action.

Where the display device 18 is a colour display unit, the counter 22, under control of the computer 12, can be caused to change colour depending on the urgency of the situation, as will be described below.

The system 10 also includes a discernible alarm means 24 connected to the computer 12. The alarm means 24 includes an audible alarm device 26, such as a siren or loudspeaker, as well as a visual alarm device 28 such as a flashing light. The alarm means 24 may be activated, for example, when the counter 22 changes colour.

The system 10 includes a data storage means 30, indicated schematically as a database in Figure 1 of the drawings. The data storage means 30 contains information relating to the display graphics to be

displayed on the display device 18 as well as to the time indicating means 20. The data storage means 30 also retains the responses made and time to instigation of those responses.

In a development of the invention, the data storage means 30 also contains information relating to the operating procedures and/or instructions to be followed by the operator in carrying out the necessary action as displayed by the graphic display device 18. Thus, for example, by pressing a predetermined key on the keyboard 16, the operator can access the operating procedures and instructions stored in the data storage means 30 which will be displayed on the display device 18. It will be appreciated that, instead, the operating procedures could be displayed on a separate screen. These procedures may then be displayed immediately on the occurrence of the fault condition to improve the efficiency of the system 10.

The data stored in the data storage means 30 may also be used to calculate or re-calculate the allowable or tolerable risk periods prior to the reactor power having to be reduced to reach a safe state, for example, probabilistic risk assessment for use in future incidents.

Upon the occurrence of a fault condition in the nuclear power station, the operator will be apprised thereof by the computer 12 becoming operational. Additionally, the alarm means 24 could be activated concurrently. Normally, the inputting of the fault condition into the computer 12 would occur automatically. Instead of automatic inputting of the fault condition, it will be appreciated that the fault condition could be entered into the computer 12 manually via the keyboard 16.

Once the fault condition has been recorded by the computer 12, the computer 12 causes the appropriate graphic display to be displayed on the display device 18. Simultaneously, the time indicating means 20 is also displayed on the display device 18. Initially, the maximum tolerable time period flashes in a first colour and the clock starts decrementing the time causing the counter 22 to be decremented. Initially, the time is decremented in hours only.

Should it be possible to recover or correct the fault in a predetermined time, once the fault is corrected, this would be entered by the operator via the keyboard 16 to clear the fault condition and to reset the system. Instead, the clearance of the fault condition may be entered into the computer 12 automatically via sensors of the plant. These sensor

could, for example, reflect the position of a valve or a circuit breaker.

If it is not possible to clear the fault condition within the specified time period, the clock then continues to count down to a predetermined time before the so-called "drop-dead" time. At the predetermined time before the mandatory "drop-dead" time, an audible warning signal is given by the device 26 of the alarm means 24. Simultaneously, the colour of the display device 20 changes to another colour and the counter 22 changes to a lesser time interval, for example, a minute display.

At the "drop-dead" time, a further audible warning is given by the device 26 of the alarm means 24 and the colour of the time indicating means 20 changes to yet a further colour. The frequency at which the time indicating means 20 flashes increases. Further, a prohibited state above the present state is displayed on the display device 18. The prohibited state is one to which the plant must not normally be taken in present circumstances.

Once a safe operating state has been reached, an audible signal is given by the device 26 of the alarm means 24. The lowest prohibited state is now displayed on the display 18 and blinks constantly.

In all cases, the audible warning given by the device 26 of the alarm means 24 is of a nagging or continuous type which demands a coded response or acknowledgment by the operator and/or will automatically alert a supervisor by default.

As an example, a display 32 is shown in Figures 2 and 3 where a motor driven pump of the plant or an associated feedwater regulating line goes inoperable. When this occurs data relating thereto is entered automatically into the computer 12 or, instead, the operator enters the appropriate data into the computer via the keyboard 16. After entering of the data, this causes the display 32 as shown in Figure 2 or Figure 3, as the case may be, to be displayed on the display device 18 of the computer 12. The time indicating means 20 is also displayed in the display 32. As indicated, in this example, two times 22.1 and 22.2 are shown in the display 32. The time 22.1 flashes white and counts down at one hourly intervals. The time 22.2 is a display, also in white. The time 22.1 is the overall tolerable period of risk for this fault condition.

It is to be noted that, in the example given, the display 32 comprises eleven symbols 40 representing the eleven operating states of the nuclear power station. These symbols 40 represent the following

states:-

symbol 40.1 - normal operating power of the reactor;

symbol 40.2 - reduced operating power of the reactor;

symbol 40.3 - hot standby;

symbol 40.4 - hot shutdown;

symbol 40.5 - normal intermediate shutdown;

symbol 40.6 - normal intermediate shutdown with residual heat removal system in action;

symbol 40.7 - monophasic intermediate shutdown;

symbol 40.8 - normal cold shutdown;

symbol 40.9 - maintenance shutdown;

symbol 40.10 - refuelling shutdown;

symbol 40.11 - refuelling shutdown with fuel removal.

The time 22.2 is the irreducible period to take the nuclear reactor of the power station from the power state, as represented by symbol 40.1, to an intermediate state, as represented by symbol 40.6

The times 22.1 and 22.2 indicated give the operator an indication of the time available to him to correct the fault. In other words, in this example, the operator would have sixty two hours to correct the fault failing which the fallback procedure must be carried out.



In this case, the limiting conditions for operation (LCO) specify that the plant must be taken from its normal power state (40.1) to the normal intermediate shutdown state with residual heat removal system in action (40.6) in seventy two hours if no recovery is possible.

When eleven hours remain, the colour of the timer 22.1 changes to amber and the count down changes to five minute intervals until "drop dead" time as indicated by the time 22.2 is reached. The time 22.2 is the minimum allowable time where attainment of the failsafe state (40.6) must be achieved. Thereafter, the time displayed by the time indicating means 20 changes to indicate to the operator the time available to move from the state represented by the symbol 40.1 to the state represented by the symbol 40.3 (in this case one hour) which flashes red. The time indicating means 20 counts this time down in five minute intervals for sixty minutes to zero time where flashing ceases, the colour changes to white and a prohibited state appears at 34 on the display 32 and is coloured yellow. The prohibited state display 34 in any LCO is used to depict the operating state which must not be entered from any lower state or mode without predetermined corrective action having been completed.

At nine hours to move from the state represented by the symbol 40.4 to the state represented by the symbol 40.6, a further time display changes from amber to red and starts flashing whilst counting down at 0.5 hour intervals to the time at which the required state (40.6) must be attained. An audible signal is emitted via the device 26 of the alarm means 24 until completion is acknowledged. The prohibited state display 34 appears after the failsafe state (40.6) has been reached. It will be appreciated that, for lower mandatory fallback states, the displayed prohibited state 34 will be lowered accordingly.

Should it be confirmed, in the first instance, that recovery of the fault is not possible within the sixty two hour time period, it may be decided to commence the ten hour fallback at once. Then, by pressing the appropriate key on the keyboard 16, the display 32 as shown in Figure 2 or Figure 3 is immediately changed to the fallback display as described above.

At all stages, a hard copy record is made of the situation for later analysis.

Heretofore, as far as the applicant is aware, it has been necessary for operators to refer to manuals to ascertain what action needs to be taken in the event

of a fault condition arising. Interpretative debate is often necessary to interpret the manuals until it is decided to declare an official fault condition resulting in time wastage which can be critical. Handwritten memoranda keep track of the elapsed time in LCO's and if more than one LCO is active, it can be extremely difficult to track each LCO independently and accurately especially with long running LCO's which straddle shift changes. This has led to delays and errors occurring, which, in the case of nuclear power stations, could have extremely serious consequences.

With the provision of the indicating system 10, in accordance with the invention, these problems are, to a large extent, obviated. The system 10 is further improved by having the information processed and displayed on a computer 12 where chances of human errors are reduced.

The system 10 can be made failsafe in the event of a failure of, for example, computer hardware or power, by instantaneously switching to a standby computer, an uninterruptable power supply and/or triggering a special limiting condition which defaults to the use of LCO hardcopy manuals which are stored nearby.

CLAIMS

1. An indicating system for use in a plant where predetermined action is required upon the occurrence of a fault condition, the indicating system including

a data processing means;

a data inputting means for inputting data into the data processing means;

a graphic display means connected to the data processing means for displaying, in graphic form, action to be taken by an operator upon the occurrence of a particular fault condition; and

a time indicating means connected to the data processing means for indicating the time available to the operator to take the appropriate action to bring the plant to a required state.

2. The system as claimed in Claim 1 in which the graphic display means, additionally, displays action to be taken in a narrative form.

3. The system as claimed in Claim 1 or Claim 2 in which the data processing means comprises a computer.

4. The system as claimed in any one of the preceding claims in which the data inputting means includes a manual inputting means by means of which the

operator enters data into the data processing means.

5. The system as claimed in any one of the preceding claims in which the data inputting means includes an automatic inputting means whereby, upon the occurrence of the fault condition, a signal is input into the data processing means.

6. The system as claimed in any one of the preceding claims in which the time indicating means comprises a clock and a time display means, the time display means being driven by the clock to be decremented as time passes so that the operator has an indication of the reducing time available in which to carry out the necessary remedial action.

7. The system as claimed in Claim 6 in which the time display means is in the form of a counter.

8. The system as claimed in Claim 7 in which the counter is operable, under the action of the data processing means, to change format depending on the urgency of the situation.

9. The system as claimed in any one of the preceding claims which includes a discernible alarm means connected to the data processing means to be activated upon the occurrence of a particular incident.

10. The system as claimed in Claim 9 in which the alarm means is of a continuous type which requires a positive response by the operator.

11. The system as claimed in any one of the preceding claims which includes a data storage means which contains information relating to graphics of the graphic display means, the time indicating means as well as action taken by the operator upon the occurrence of the fault condition.

12. The system as claimed in Claim 11 in which the data storage means, additionally, contains information relating to detailed procedures to be followed by the operator in carrying out the appropriate action.

13. A method of operating a plant where predetermined action is required upon the occurrence of a fault condition, the method including

graphically displaying a sequence of actions to be taken by an operator on the occurrence of a fault condition in the plant; and

indicating permissible time limits in which the action must be taken.

14. The method as claimed in Claim 13 which includes making available predetermined data to enable the sequence of actions to be displayed graphically.

15. The method as claimed in Claim 13 or Claim 14 which includes displaying the time in a predetermined format and causing the displayed time to be decremented.

16. The method as claimed in Claim 15 which includes, as critical time periods are approached, causing the displayed time to change format.

17. The method as claimed in any one of the preceding claims which includes, upon the occurrence of a fault condition, activating an alarm means.

18. A new indicating system for use in a plant where predetermined action is required upon the occurrence of a fault condition substantially as described and as illustrated herein.

19. A new method of operating a plant where predetermined action is required upon the occurrence of a fault condition substantially as described herein.



**Application No:** GB 9420797.4  
**Claims searched:** 1-17

**Examiner:** Mr Andrew Bartlett  
**Date of search:** 20 March 1995

**Patents Act 1977**  
**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK CI (Ed.N): G3N (NGK2A,NGK2B,NGK2,NG1A1,NG1A3,NG1A5,NG1A9); G6C (CDF)

Int CI (Ed.6): G05B 9/02 & 23/02; G21C 17/00; G21D 3/02,3/04 & 3/06

Other: ONLINE:- WPI

**Documents considered to be relevant:**

Category	Identity of document and relevant passage	Relevant to claims
A	EP0411869 A2 WESTINGHOUSE See whole document.	1 & 13
A	EP0099681 A1 WESTINGHOUSE See whole document.	1 & 13
A	US4853175 A T L BOOK See column 10 lines 18-27 in particular.	1 & 13

X Document indicating lack of novelty or inventive step  
Y Document indicating lack of inventive step if combined with one or more other documents of same category.  
& Member of the same patent family

A Document indicating technological background and/or state of the art.  
P Document published on or after the declared priority date but before the filing date of this invention.  
E Patent document published on or after, but with priority date earlier than, the filing date of this application.